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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,444,648**, on October 9, 2003, by **TESCO CORPORATION**, assignee of Per G. Angman and Maurice W. Slack, for "Anchoring Device for a Wellbore Tool".

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ABSTRACT OF THE INVENTION

A self-anchoring tool is disclosed that can be positioned downhole and used in casing. The tool has an architecture that supports installation by running downhole and into engagement with a groove formed in the casing, called the profile nipple. The tool readily supports use of weak materials such as plastic, for components of the tool that must be drilled to reopen the wellbore after cementing. As such, no restriction is needed in the casing for accepting or latching the tool and the portion of casing including the groove can be installed at the start of the drilling operation. In addition, the profile nipple can be used to engage other drilling tools and, therefore, can already be in place when the final well depth (TD) is reached.

Anchoring Device for a Wellbore Tool

Field of the Invention

This invention relates to an anchoring device for a wellbore tool and, in particular, an anchoring device for expanding into a liner groove such as for use in a cement float tool, bridge plug or packer and method for using same. In addition, the invention relates to a sealing cup, which assists in the anchoring of a tool in a wellbore.

Background of the Invention

The method of constructing wells using casing as the drill string, where the bottom hole drilling assembly is deployed through the casing, does not permit incorporating devices such as a cement float shoe directly into the casing string in the conventional manner. Furthermore, the casing cannot be provided with an internally upset interval, on which to land a device introduced after drilling, as this would restrict the casing internal diameter preventing deployment of the bottom hole drilling assembly. In Canadian patent application CA 2,311,160, Vert and Angman disclose a cement float that can be positioned downhole in a casing string provided with a suitable profile nipple.

The function of a typical installed cement float requires it to act as a check valve allowing flow down a casing string suspended in a borehole but preventing backflow, sealing the casing bore from differential bottom pressure. This pressure differential exists during well cementing processes after wet cement is placed in the casing and displaced into the borehole-casing annulus by a lighter fluid. It is created by the difference in hydrostatic head between the cement and lighter displacing fluid, commonly water, and in turn induces an axial load that must be reacted into the casing. This axial load increases with the differential pressure and the sealed area thus the required structural capacity of such devices is greater for larger diameter casing and deeper wells.

Summary of the Invention

A readily drillable cement float tool has been invented, having a novel architecture, supporting use of non-metal components and in-situ installation in a wellbore completion

operation after drilling a wellbore with casing. The cement float tool is made for running downhole, preferably by pumping, and into engagement with an internal groove formed into the casing wall. The element of casing carrying the groove is herein called the profile nipple. As such, no restriction is needed in the casing for accepting or latching the cement float tool, and the profile nipple can be installed at the start of the drilling operation and therefore can already be in place when the final well depth (TD) is reached. In addition, the profile nipple can be used to engage other drilling tools.

In accordance with a broad aspect of the present invention, there is provided a tool for use in a casing string to be used to line a wellbore, the casing including an annular groove somewhere in its length, the annular groove having a diameter greater than the inner diameter of the casing string, the tool supporting movement through the casing string and comprising:

- a generally tubular mandrel having coarse exterior grooves, an upper end and a lower end;
- a bottom sealing member disposed below the mandrel having a bore therethrough;
- a top sealing member disposed above the mandrel having a bore therethrough;
- the top and bottom seal members coaxially attached to the respective upper and lower mandrel ends;
- a radially resilient anchor carriage having a generally cylindrical outer surface and an inner sidewall into which coarse grooves are placed corresponding to those on the exterior of the mandrel, the carriage being sized to pass through the casing string when compressed and yet elastically expandable to have an outer diameter greater than the casing internal diameter and its length being selected to be less than the casing annular groove length;
- the anchor carriage being mounted on the mandrel having their coarse grooves engaged, where the fit of the grooves thus engaged is arranged to be close with the anchor carriage compressed to fit inside the inner diameter of the casing string in which it is to be used and loose fitting, but still engaged, with the anchor carriage expanded and latched into the annular groove of the casing string; and

- the sealing members creating a seal between the mandrel and the casing string, the seal being sufficient to substantially seal against fluids passing between the mandrel and the casing string at fluid pressures encountered in a wellbore operation during installation and with the anchor carriage latched into the groove of the casing string.

The mandrel and the anchor carriage are formed to interengage, both when the tool is being passed through the casing and the anchor carriage is compressed about the mandrel and when the tool is anchored into the groove of the casing and the anchor carriage is expanded into the groove. The angles and the materials of the coarse grooves on the mandrel and the anchor carriage are selected to maintain interengagement at the loads encountered during installation and operation.

In one embodiment, the coarse grooves are formed as threads and in another embodiment, they are axi-symmetric and extend circumferentially.

The anchor carriage is preferably formed as a composite structure having an outer shell of durable material such as steel and inner coarse threads formed of drillable material attached to the outer shell. Said drillable material comprising the threads is more preferably a non-metallic such as plastic. The outer shell thickness is selected not to exceed the depth of the annular groove provided in the casing. The radial compliance of the anchor carriage is preferably provided by configuring the anchor carriage to have a portion of the wall removed from its upper and lower ends to form notches and the wall in the mid-section between these notches cut on a helical pattern coinciding with the location of a thread root to thus create a structure where the notched upper and lower intervals act as C-rings joined by a spring coil defined by the helically cut mid-section. It will be apparent that application of radial compressive displacement to such a structure will have the effect of closing the C-ring sections and tightening the helically cut interval thus overall reducing the anchor carriage diameter, which diameter reduction is resisted primarily by increase of through-wall flexural stress providing the desired radial compliance. It is further preferable if the mid-section of the anchor carriage is configured

as a right hand helix. Under application of right hand drilling torque, the right hand helix geometry of the anchor carriage mid-section, when latched in the groove thus tends to expand the helix engaging the confining surface of the groove. This engagement mobilizes a frictional self-locking effect and thus resists rotation making it easier to drill the portions of the tool protruding into the internal bore of the casing. This preferred combination of materials and geometry thus provides that the tool: can withstand the rigours of passage downhole during installation; has sufficient elastic compliance to accommodate the diameter reduction required to permit insertion into the casing bore and correlative elastic diameter expansion to latch into the groove; but can be drilled out to permit the removal of substantially all of the tool should this be necessary, for example, to extend the borehole.

In an embodiment including cuts along the anchor carriage, as between helical sections, the facing edges of the cut can be formed to engage together, as by use of frictional engagement or a ratchet effect.

In an alternate embodiment, the radial resiliency of the anchor carriage is provided by configuring it to have a portion of its sidewall removed along its entire length to thus create a structure where the entire anchor carriage acts as a C-ring.

The tool can be any tool for which is desired to be anchored downhole, for example, a cement float, a bridge plug or a packer.

When the tool is configured as a cement float tool it will typically include a bore through the mandrel extending from its upper end to its lower end and a flow control assembly mountable on the tool to prevent flow of fluids through the bore of the mandrel at least from its lower end to the upper end. It may include a shearable plug in sealing position within the bore to support a pump down installation. In one embodiment, the method includes increasing fluid pressure above the cement float tool once the cement float is latched into the groove to shear the shearable plug from the bore.

Installation of the tool can be achieved by running on wireline or tubing or by pumping down.

In accordance with a further broad purpose of the present invention, a sealing cup is provided for a tool to seal against differential pressure about the tool in a wellbore casing. The seal cup comprises:

- a base having a first end and a second end, a bore therethrough, means for attachment to a tool at its first end and its diameter selected to match or nearly match the drift or minimum running diameter of the casing in which it is to be used;
- a lower elongate generally tubular interval extending from the base and having an outer end where at least one raised circumferential external seal land is provided adjacent the outer end of the tubular interval, the diameter of the seal land being selected to allow sealing engagement with the casing inner diameter in which it is to be used, the external surface of the tubular interval generally taper from the seal land to the base, the wall thickness of the tubular interval generally increasing from the outer end toward the base; and
- the external surface of the tubular interval including an external cup surface between the seal land and the base, which under bottom pressure is capable of conducting seepage fluid from adjacent the seal land to the upper end of the base to act against pressure invasion about the external surface.

The seal cup material is selected to be more compliant than that casing material, which is generally steel, in which it is to be used and is selected with consideration as to the pressure loads in which it must seal. Of course, the material used must also be considered for thermal response, such as expansion and compliancy, to achieve a sealing action.

In operation the seal cup tends to be self anchoring under application of bottom differential pressure, i.e., axial load generated by the pressure differential is reacted by frictional sliding resistance between the seal cup tubular interval and the confining casing

wall. This self anchoring mechanism arises because the exterior seal formed at the outer end of the seal cup permits differential pressure is applied as an internal pressure across the tubular interval wall. This effect is also permited by an external cup surface between the seal land and the base, which under bottom pressure is capable of conducting seepage fluid from adjacent the seal land to the upper end of the base. This surface, which permits seepage, can, for example, be roughened, scored, formed with seepage grooves, or formed of porous material.

The compliance of the selected structural plastic, allows the tubular interval to expand readily under application of modest pressure until it contacts the much lower compliance confining casing wall. Application of additional pressure serves to directly increase the interfacial contact stress and proportionately the axial force required to induce frictional sliding between the seal cup tubular interval and the casing wall. Axial load arising from differential pressure acting across the base may thus be reacted in part by tension where it is joined to the tubular interval, reducing or even eliminating the axial pressure end load that needs to be reacted through the anchor carriage.

It will be appreciated that this self-anchoring mechanism greatly reduces the load capacity required from an anchoring system on a tool and thus, enhances the anchoring properties in a tool. For example, with consideration as to the anchoring tool described herein above, in combination with shear area efficiencies gained by reacting load from the mandrel into the anchor carriage through coarse thread engagement, this seal cup architecture provides a substantial improvement in the ability to use lower strength, readily drillable materials in the mandrel and anchor carriage.

Brief Description of the Drawings

A further, detailed, description of the invention, briefly described above, will follow by reference to the following drawings of specific embodiments of the invention. These drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. In the drawings:

Figure 1 is a vertical section through a portion of well casing including a cement float tool according to the present invention in a configuration for passing through the well casing as it would appear being pumped down the casing during installation;

Figures 2 and 3 are vertical sectional views of the cement float tool of Figure 1 in latched positions in a portion of well casing. In Figure 2 the float valve is open permitting flow of fluids downwardly through the cement float tool, while in Figure 3 the float valve is closed preventing reverse flow therethrough;

Figure 4 is a perspective view of a bottom cup seal according to one aspect of the present invention and useful in a cement float tool according to the present invention; and

Figure 5 is a perspective view of an anchor carriage useful in a cement float tool according to the present invention as it would appear expanded.

Figure 6 is a perspective view of a main body, with a key way and key, useful in a cement float tool.

Figure 7 is a perspective view of an anchor carriage useful with the main body of Figure 6.

Description of the Preferred Embodiments of the Invention

Referring to Figures 1 to 3, a cement float tool 10 according to the preferred embodiment of the present invention is shown. Cement float tool 10 is configured to pass through a tubular string of casing, a portion of which is shown at 1. Casing 1 has a specified minimum inner diameter ID_1, commonly referred to as the drift diameter, so as not to limit the size of a tool that can pass therethrough. An annular groove 2 (Figures 2 and 3) is placed, as by machining, in a profile nipple 3 adapted to connect into the distal end of the casing string by, for example, threaded connections illustrated by the casing to profile nipple connection 6. The diameter D_2 in groove 2 is slightly larger than the minimum inner diameter of the casing tubing. The cement float tool is configured to be pumped

through a string of casing and to latch into and be retained in the annular groove, as will be more fully described hereinafter. The annular groove 2 is formed to permit the cement float tool to be accepted without consideration as to the rotational orientation of the cement float tool in the casing.

Figure 1 shows the cement float tool in a position being moved through a section of casing while Figures 2 and 3 show the cement float tool 10 secured in the casing in the annular groove of a profile nipple.

Referring now to Figure 2, cement float 10 includes a mandrel 11 joined to top seal cup 12 and bottom seal cup 13 by generally sealing upper and lower threaded connections 14 and 15 respectively. These parts have a longitudinal bore 17 therethrough extending from upper end opening 18 in top seal cup 12 to lower end opening 19 in bottom seal cup 13. The cement float is sized to pass through ID_I, of the size of casing in which it is intended to be used with seal cups 12, 13 sealing against the ID_I. Upper and lower threaded connections 14 and 15 respectively, are provided to facilitate manufacture and assembly and to allow more optimal selection of materials.

Top seal cup 12 is formed from a compliant (relative to casing material), drillable material, such as polyurethane, and can have a surface coating of wear resistant material. Top seal cup can include at least one elongate upper lip 20, configured with at least one external upper seal land and selected to adequately seal between the casing and main body against top pressure required to pump the cement float tool down the casing until latched in the profile nipple 3 and any subsequent top pressuring as may be required to, for example, fail a shear plug as described hereinafter. In the illustrated embodiment, upper seal cup 12 includes two lands 21 having their diameter length and spacing selected so as to span small gaps such as at a connection illustrated by the position of the seal lands in connection 6. Thus described, it will be apparent to one skilled in the art that top seal cup 12 is generally configured in a manner known to the industry for a cementing plug, a cement wiper plug or a packer cup.

Similarly, bottom seal cup 13 is formed from a compliant (relative to casing material), drillable structural material such as fiber reinforced polyurethane selected to operate under the pressure loads to be expected in operation. It is shaped as by molding or machining to have a base 22 integral with an elongate seal tube 23 having its upper end 24 attached to the base 22 and its lower end 25 open, thus forming a downward facing cup. The external surface 26 of bottom seal cup 13 is profiled to have at least one slightly raised circumferential external seal land 27 on the seal tube lower end 25, with diameter selected to allow sealing or near sealing engagement with casing inner diameter, such as the profile nipple 3 directly below groove 2 in which it is to be used, a diameter at the base 22 closely matching the drift or minimum running diameter and the intervening interval 23' extending from seal land 27 to the seal tube upper end 24 generally tapered to blend with the base 22. Referring now to Figure 4, the external surface 26 is further provided with a circumferential seepage groove 28 directly adjacent the seal land 27 on its base 22 side and one or more seepage grooves 28' extending from the seal land upward toward the base, which grooves are sized to permit passage therethrough of well bore fluids that might seep past lower seal cup 13 when acting to seal against bottom pressure. External surface 26 can further be provided with surface acting wear resistant material, to provide durability against damage during, for example, during run in.

Referring now to Figure 2, the external surface of the mandrel 11 carries external coarse threads 29 creating a means of structurally reacting loads from the cement float tool. To ensure adequate load transfer capacity while yet being readily drillable, mandrel 11 is preferably made from a rigid, strong yet frangible material such as a reinforced phenolic or high temperature granular reinforced resin based grout.

A radially resilient anchor carriage 50 is mounted coaxially about mandrel 11 and provided with internal coarse threads 51 engaging the external coarse threads 29 of mandrel 11 together forming a threaded connection therebetween. Numerous variations in the coarse thread form, such as say buttress thread forms, may be employed to achieve various design purposes within the scope of the present invention, however a symmetric V-thread having an included angle of approximately 90°, i.e., the angles of stab flank 53'

and load flank 53" with respect to the tool axis both approximately 45° from the long axis of the tool, as illustrated here in its preferred embodiment, was found to provide satisfactory pump down and anchor performance combined with simplicity of manufacture.

Referring also to Figure 5, in its preferred embodiment, the anchor carriage 50 is formed as a composite structure having an outer shell 52 of durable material such as steel attached to an inner layer 54 made of a weaker more drillable and compliant material, such as fibre reinforced polyurethane, into which the inner coarse threads 51 are formed. The thickness of outer shell 52 is selected not to exceed the depth of the annular groove 2 provided in the profile nipple 3 and into which the anchor carriage is to land such that the high strength outer shell 52 need not be drilled out when drilling out the remainder of the cement float tool to the casing internal diameter ID_1 after cementing. To further enable load transfer between inner layer 54 and outer shell 52 the inner surface of outer shell 52 is provided with a plurality of spaced internal grooves 55 engaging matching teeth 56 on the exterior of the inner layer 54. The internal grooves 55 may be axi-symmetric, helical or a combination, and are readily placed by machining, as for example multi-start threads having a pitch corresponding to that of the coarse threads 51. The engaging teeth 56 are readily created by casting the material comprising the inner layer 54 into the internal grooves 55 cut into the shell 52. Even more beneficial load transfer capability is achieved where the internal grooves 55 and mating teeth 56 are shaped to have reverse angle flanks 57, so as to create a dove-tail joint interconnection.

The radial resilience of anchor carriage 50 allows it to be compressed down to fit inside the diameter ID_1 of the casing 1 for installation (Figure 1) and yet elastically expand (Figure 2) sufficient to engage the groove 2 of the profile nipple 3 when released. Correspondingly, the geometry of threaded connection 53 is selected to ensure anchor carriage 50 can sufficiently compress for installation, as shown in Figure 1, and yet still provide substantial engagement with the mandrel and, therefore, load transfer when expanded into groove 2 as shown in Figure 2.

The radial compliance of anchor carriage 50 is preferably provided by configuring it to have a portion of its wall removed from its ends to form upper and lower notches 58 and 59 respectively and a helical cut 60 placed through the wall in mid-section 61 between notches 58 and 59 and coinciding with the location of the root of the internal coarse threads 51. This combination of notches connected by a helical cut thus create a structure where the ends about upper and lower notches 58 and 59 define what behave as upper and lower C-ring intervals 62 and 63 respectively, which intervals are joined by a spring coil defined by the helically cut mid-section 61. It will be apparent that application of radial compressive displacement to such a structure will have the effect of closing the C-ring sections 62 and 63 and tightening the helically cut mid-section interval 61 thus overall reducing the diameter of the anchor carriage 50, which diameter reduction is resisted primarily by increase of through-wall flexural stress providing the desired radial resilience. The circumferential width Wn of notches 58 and 59 is selected to accommodate a diameter reduction of the C-ring intervals 62 and 63 sufficient to permit insertion of the anchor carriage into casing of minimum internal diameter ID_1. Relating now the anchor carriage as shown in Figure 5 mounted on mandrel 11 as shown in Figures 1 to 3, in another aspect of the preferred embodiment the lower notch 59 may be further utilized as a means to mate with a key 64 fastened in the corresponding exposed interval of the mandrel 11, where such a key locks the relative rotational position of the anchor carriage 50 on the threads 51 of the mandrel to prevent 'unthreading' occurring during installation and to further resist drilling torque loads applied to main body 16 during drill-out. In particular, when pin 64 is rigidly secured to the mandrel and in, for example, notch 59, the carriage cannot rotate past the pin, to be threaded off the mandrel.

It is useful to configure the helically cut mid-section interval 61 of the anchor carriage 50 is configured as a right hand helix. This geometry is preferred because under application of right hand drilling torque as would typically be used to drill out the cement float tool, the right hand helix geometry of the anchor carriage mid-section 61, when latched in groove 2, tends to expand the confined helix, creating a frictional self-locking effect resisting rotation and thus improving drill-out performance.

In an alternate embodiment, the radial resilience of anchor carriage 50 is achieved by omitting the helical cut 60 and one of the upper or lower notches 58 and 59 and extending the remaining notch along the full length of the anchor carriage to thus create a structure where the entire anchor carriage 50 acts as a C-ring. Where the radial compliance is thus obtained with a C-ring structure, the interlocking teeth of the coarse threads 53 may be provided as axi-symmetric rings and grooves as a further variation of this alternate embodiment. In this configuration, the C-ring must be 'sprung open' to facilitate initial placement of the anchor carriage 50 onto the mandrel 11.

Referring now to Figure 2, a float valve or check valve is positioned in bore 17 of main body 16 to permit only one-way flow therethrough from upper end opening 18 to lower end opening 19. While other one-way check valves such as, for example, ball valves, are useful, the illustrated check valve is a flapper valve 70 and includes a flapper 71 mounted via a hinge pin 72 to a flapper valve housing 73. As will be appreciated by a person skilled in the art, flapper 71 is formed to seal against a seat 74 formed at the lower end opening 19 in the base 22 of lower cup 13 when a flow of fluid tends to move through the bore in a direction from lower end opening 19 to upper end opening 18 (Figure 3). Flapper 70 is normally biased into the sealing position against seat 74 by a spring (not shown) such as, for example, a torsion spring acting about hinge pin 72. Flapper valve housing 73 may be secured to lower cup base 22 by various means including threaded engagement with the inside annular surface 76 of recess 77 provided in bottom seal cup base 22. Other valve types such as, for example, ball valves can be used, as desired, provided that they are durable enough to withstand the passage of cement therethrough. In other embodiments, seal is provided in the bore of the mandrel and in other embodiments an end of the mandrel extends out past one or both of the seal cups 12, 13.

Referring now to Figure 1, for pumping downhole, a releasable plug 80 is disposed in bore 17. Releasable plug 80 is selected to remain in plugging position within bore 17 up to a selected maximum pressure. At pressures above the selected maximum pressure, plug 80 is driven out of bore 17. While many suitable pressure releasable plugs are known, the illustrated cement float tool includes a plug having a flange 81 sealingly

engaged on an upset shoulder 82 in top seal cup 12. When pressure acting against the plug is increased above the selected maximum pressure, the flange shears away from the plug body and the plug is expelled from bore 17. The length of plug 80 may be selected such that it extends past flapper valve 70 thus mitigating against possible damage to flapper 71 when the plug is expelled. The plug can be retained by several different means such as, for example, bonding of flange 81 into shoulder 82. In another embodiment, a burst plate is used rather than a plug that is expelled. In a standard completion operation, the selected maximum pressure for expelling the plug is greater than the normal pressure required to pump the plug down the casing. For example, the pressure to pump down a cement float tool would typically be less than 500 psi. In a one embodiment, releasable plug 30 is selected to remain in place in the bore unless fluid pressures above the plug exceed about 1500 psi.

Referring now to Figure 2, anchor carriage 50 has a length between its leading edge 50' and its trailing edge 50" that is less than the width w of groove 2 such that the anchor carriage 50 can completely expand into the groove. Groove 2 is formed with upper and lower shoulders 4 and 5 respectively, that step generally abruptly from D_2 to ID_1. The exposed corners of upper and lower shoulders 4 and 5 are preferably radiused or chamfered to facilitate movement therepast of equipment, for example during drilling. However, any radius or chamfer should not be so great as to inhibit or jeopardize firm latching of the anchor carriage 50 into groove 2. When the anchor carriage 50 expands into groove 2 it becomes latched in it by abutment of leading edge 50' against lower shoulder 5 of groove 2 (Figure 2). Upwards movement of cement float tool 10 is limited by abutment of edge 50" against the upper shoulder 4 of the groove 2 (Figure 3). The outward facing corner of leading edge 50' is preferably curved or chamfered to facilitate movement through the casing string and over discontinuities such as might occur at casing connections. Any such curvature or chamfering, however, must be of a limited radius or depth so as to avoid interference with secure latching of the anchor carriage 50 into groove 2 and abutment against lower shoulder 5.

Figures 6 and 7 show another embodiment of a cement float tool. In the illustrated embodiment, the carriage and mandrel are formed such that the carriage is detachably engaged to the mandrel when the carriage is compressed against the main body, but will be released from engagement with the main body when the carriage is allowed to expand. In the illustrated embodiment, a key is employed to lock the carriage to the main body (mandrel) when the carriage is compressed onto the mandrel to accommodate insertion in the casing. This alternate embodiment reduces the drag produced by the carriage while traversing the casing interval as required for pumping downhole, thus enjoying the further benefits of: requiring less differential pump down pressure across the upper sealing member (seal cup) which lower differential pressure in turn tends to reduce wear on the upper sealing member, reduced wear on the outer surface of the anchor carriage and less chance of the tool becoming stuck at locations where the casing inside cross sectional area is reduced or constricted such as connections (particularly where such constrictions occur abruptly).

This key lock architecture uses a generally rectangular cross section elongate key fitting into matching keyways provided through the plastic internal threads of the generally helically cut anchor carriage and the external threads of the mandrel analogous to the well known means of keying a shaft to say a pulley, preventing relative rotation. The keyways are aligned when the carriage is in its compressed position on the mandrel as required for running through the casing prior to latching into the profile nipple. With respect to the key, the keyway in the carriage is arranged to be loose fitting and the keyway in the mandrel close fitting or preferably tight fitting so that once installed the key tends to stay engaged in the mandrel keyway slot with respect to relative radial movement. Locking of the key to the mandrel may be further assured by the use of small fasteners, such as screws, or glue. The depth of the key with respect to the anchor carriage thread height is arranged so that within the range of radial expansion possible when the carriage is travelling in the casing the keyway engages the key but under the greater outward radial expansion allowed when the carriage enters the profile nipple and tends to expand the keyway will become disengaged from the key over at least its lower length so as to permit the carriage to expand and thus simultaneously uncoil along its helical interval.

Thus arranged, it will be evident when running in the casing the key tends to prevent the carriage, acting as a coiled helical spring, from expanding by reacting the forces allowing uncoiling primarily through the key and into the mandrel. It will be apparent that at the ends of the helix there is an inward radial component to the force required to maintain engagement of the helix in the key. The lower end of the keyway in the carriage helix thus acts as a latch where depending on the angle of contact between the keyway and the contacting lower edge of the key, the latch can be arranged to tend to release, unless restrained by an external radial force as provided by contact with the casing. In a manner known to the art, this angle is selected with reference to the in-situ friction coefficient to ensure release when entering the profile nipple but otherwise arranged to minimize the radial force applied by the casing to thus reduce wear and drag and obtain other benefits as described above.

In operation, prior to cementing cement float tool 10 is placed inside casing 1, suspended in a wellbore, and displaced downhole by pumping fluid, typically drilling fluid, into the proxil end of the casing string. Top seal cup 12 tends to prevent flow of such fluid past the cement float tool creating a downward axial force as a function of the applied top differential pressure required to overcome drag where the top seal cup 12, bottom seal cup 13 and anchor carriage 50 contact the casing. In general, the sum of these drag components must not require excess installation pressure. To prevent such excess drag from upper cup 12 seal friction, in the preferred embodiment, the wall thickness and length of the seal lip are selected in combination with the diameter below the seal land 21 so that under differential pressure loads required to pump down the cement float tool a clearance is maintained between the seal lip and internal surface of the casing except at the upper seal land 21 to prevent contact developing outside the seal land while yet providing sufficient compliance to ensure an adequate seal will be formed under the expected variations in internal casing diameter. Drag arising from the tendency of the elastically compressed anchor carriage to expand against the confining inside diameter of the casing is affected by frictional interaction between the engaged stab flanks 53' in the coarse threaded connection 53 as the drag load is reacted between the anchor carriage 50 and mandrel 11. Selecting too shallow a stab flank angle results in a tendency for the cement float tool to 'jam' during installation, however as more fully described below, this

angle also affects the anchor structural behaviour. As indicated earlier, the illustrated stab flank angle of approximately 45° (with respect to the cement float tool axis) was sufficiently steep to prevent jamming. Drag arising from the bottom seal cup 13 during installation naturally tends to be minimized as this downward facing cup is not loaded under top pressuring required for pump down.

Once the cement float tool has been displaced downward to the point where the anchor carriage is latched into the groove 2, application of top pressure produces a downward acting axial load that is transmitted through the main body 16 and coarse threaded connection 53 where the illustrated stab flank angle of approximately 45° is sufficiently shallow to promote expansion of the anchor carriage, pressing its outer shell 52 outward and into positive contact with the confining surface of groove 2. This action tends to ensure the anchor carriage is pressed outward and fully engages the groove along its length and especially at lower shoulder 5 where the remaining axial load is reacted into the casing. It will be apparent that the interacting mandrel and anchor carriage functions as an anchor so that pressure load sealed across the top seal cup is reacted by the anchor into the casing allowing the releasable plug 80 to be blown out and the flapper valve 70 to function as a check valve during flow of fluids as required for cementing.

Following placement of the cement behind the cement by displacement with a lighter fluid as required in a typical completion, reduction of pump pressure at the proxil end of the casing string results in a tendency for the heavier cement column to 'U-tube' back into the casing. Referring now to Figure 3, this flow is prevented by the flapper valve 70 with consequent increase of differential bottom pressure across bottom seal cup 13. Initial bottom pressure load across the bottom seal cup 13 tends to make it inflate, seal and slide uphole; but this sliding is soon prevented by the interaction of the anchor function of the cement float tool, in an analogous fashion to top pressuring, where the illustrated load flank 53" angle of approximately 45°, like the stab flank 53', causes positive radial engagement between the anchor carriage shell 52 and the groove 2, preventing jump-in of the anchor carriage 50. But unlike the transient top pressure load required to fail and

expel releasable plug 80, sealing against bottom differential pressure must be sustained until the cement sets. This may take several hours under typical downhole conditions of elevated temperature and high differential pressure. If the bottom seal cup 13 only provides a sealing function, the full pressure end load must be borne by the threaded connection 53 for this time period. Under such conditions, the stress carried by the plastic, preferably used to form the internal coarse threads 51, tends to cause creep, which over sufficient time will lead to failure. It will be apparent that where such thread creep occurs, the bottom cup 13 will continue to slide.

However, when configured according to the teachings of the present invention, lower cup 13 has a tendency to resist such sliding through a pressure activated self anchoring mechanism. This self anchoring mechanism is induced under application of differential pressure from below because the location of the external seal 26 at the lower end of the seal tube 23 in combination with the seepage grooves 28 and 28' ensures the full pressure differential occurs across the wall of seal tube 23, tending to cause it to expand, contact and become restrained by the profile nipple 3, under application of sufficient pressure. Application of additional pressure serves to increase the interfacial contact stress, which contact stress gives rise to frictional resistance to axial sliding of the seal tube 23. The combination of selecting the lower cup material to be more compliant than the casing and ensuring minimum clearance is maintained between the seal tube and profile nipple 3, as taught herein, promotes contact at lower differential pressure and thus greater resistance to sliding for a given differential pressure. The wall thickness and length of seal tube 23 are arranged to promote self anchoring under application of differential pressure where the wall thickness of seal tube 23 is generally tapered to thicken from its lower end 25 to its upper end 24, and its length selected to be long enough to ensure all or a significant amount of the differential pressure end load for the intended application is thus reacted by this self anchoring mechanism. The wall thickness is thickened to ensure axial strength to resist sliding is increased coordinate with the length of seal tube in contact with the casing wall, while yet minimizing the hoop stiffness to encourage earlier wall contact with increasing pressure and thus optimize resistance to sliding. As described, the bottom seal cup is seen to function both seal

against bottom pressure and react the associated end load so that the anchor function of the cement float tool is largely required to correctly locate the tool and function as an initiator at lower pressure until the self anchoring mechanism of the bottom cup is fully activated.

It will be apparent that many other changes may be made to the illustrative embodiments, while falling within the scope of the invention and it is intended that all such changes be covered by the claims appended hereto.

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Claims:

1. A tool for use in a casing string to be used to line a wellbore, the casing including an annular groove somewhere in its length, the annular groove having a diameter greater than the inner diameter of the casing string, the tool supporting movement through the casing string and comprising:

- a generally tubular mandrel having coarse exterior grooves, an upper end and a lower end;
- a bottom sealing member disposed below the mandrel having a bore therethrough;
- a top sealing member disposed above the mandrel having a bore therethrough;
- the top and bottom seal members coaxially attached to the respective upper and lower mandrel ends;
- a radially resilient anchor carriage having a generally cylindrical outer surface and an inner sidewall into which coarse grooves are placed corresponding to those on the exterior of the mandrel, the carriage being sized to pass through the casing string when compressed and yet elastically expandable to have an outer diameter greater than the casing internal diameter and its length being selected to be less than the casing annular groove length;
- the anchor carriage being mounted on the mandrel having their coarse grooves engaged, where the fit of the grooves thus engaged is arranged to be close with the anchor carriage compressed to fit inside the inner diameter of the casing string in which it is to be used and loose fitting, but still engaged, with the anchor carriage expanded and latched into the annular groove of the casing string; and
- the sealing members creating a seal between the mandrel and the casing string, the seal being sufficient to substantially seal against fluids passing between the mandrel and the casing string at fluid pressures encountered in a wellbore operation during installation and with the anchor carriage latched into the groove of the casing string.

2. The tool of claim 1 wherein the coarse grooves are formed as threads

3. The tool of claim 1 wherein the coarse grooves are axi-symmetric and extend circumferentially.

4. The tool of claim 1 wherein the anchor carriage is formed as a composite structure having an outer shell of a first material and inner coarse threads formed of drillable material, attached to the outer shell.

5. The tool of claim 4 wherein the outer shell thickness is selected not to exceed the depth of the annular groove provided in the casing.

6. The tool of claim 1 wherein the anchor carriage includes a C-ring portion to provide radial resiliency.

7. The tool of claim 6 where the anchor carriage includes a C-ring at each end and a helically cut spring coil section joined therebetween.

8. The tool of claim 7 wherein the helically cut spring coil section is configured as a right hand helix.

9. A sealing cup is provided for a tool to seal against differential pressure about the tool in a wellbore casing. The seal cup comprises:

- a base having a first end and a second end, a bore therethrough, means for attachment to a tool at its first end and its diameter selected to match or nearly match the drift or minimum running diameter of the casing in which it is to be used;
- a lower elongate generally tubular interval extending from the base and having an outer end where at least one raised circumferential external seal land is provided adjacent the outer end of the tubular interval, the diameter of the seal land being selected to allow sealing engagement with the casing inner diameter in which it is to be used, the external surface of the tubular interval generally taper from the

seal land to the base, the wall thickness of the tubular interval generally increasing from the outer end toward the base; and

- the external surface of the tubular interval including at least one seepage groove between the seal land and the base, which under bottom pressure are capable of conducting seepage fluid from adjacent the seal land to the upper end of the base to act against pressure invasion about the external surface.

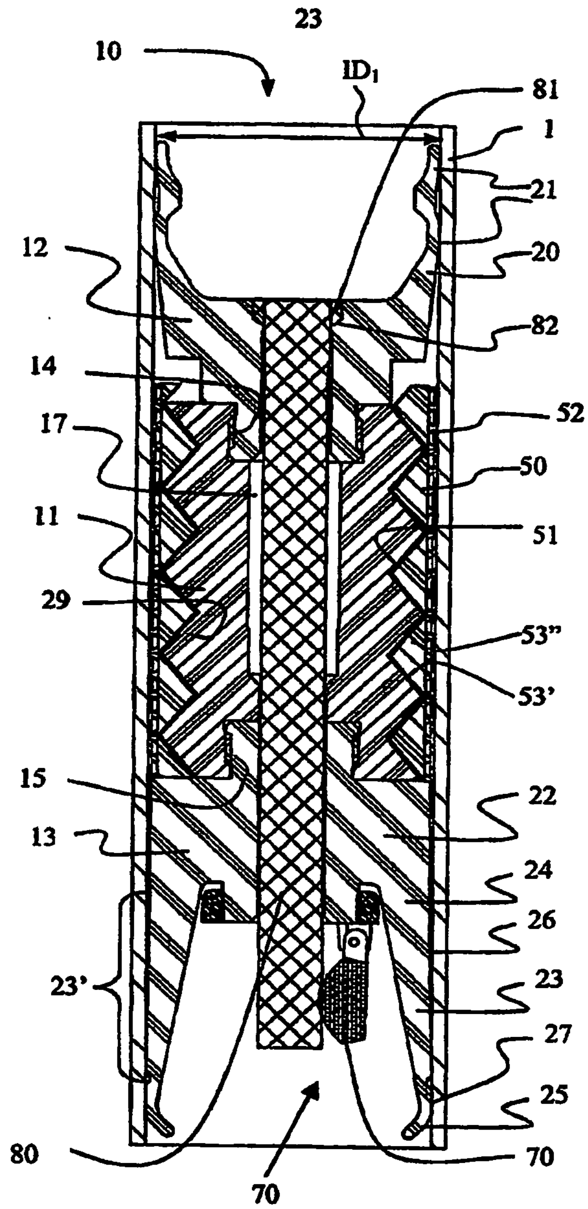
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Figure 1

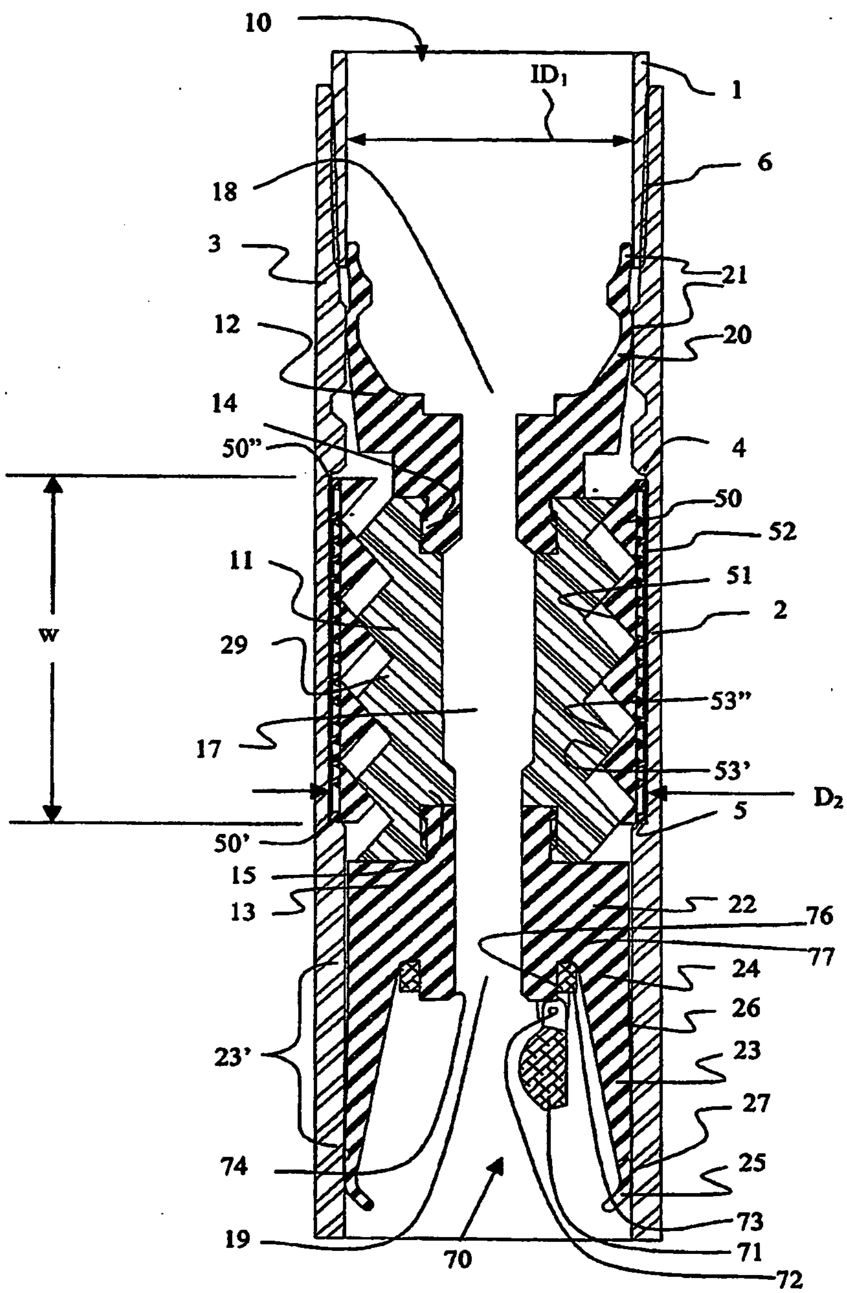
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Figure 2

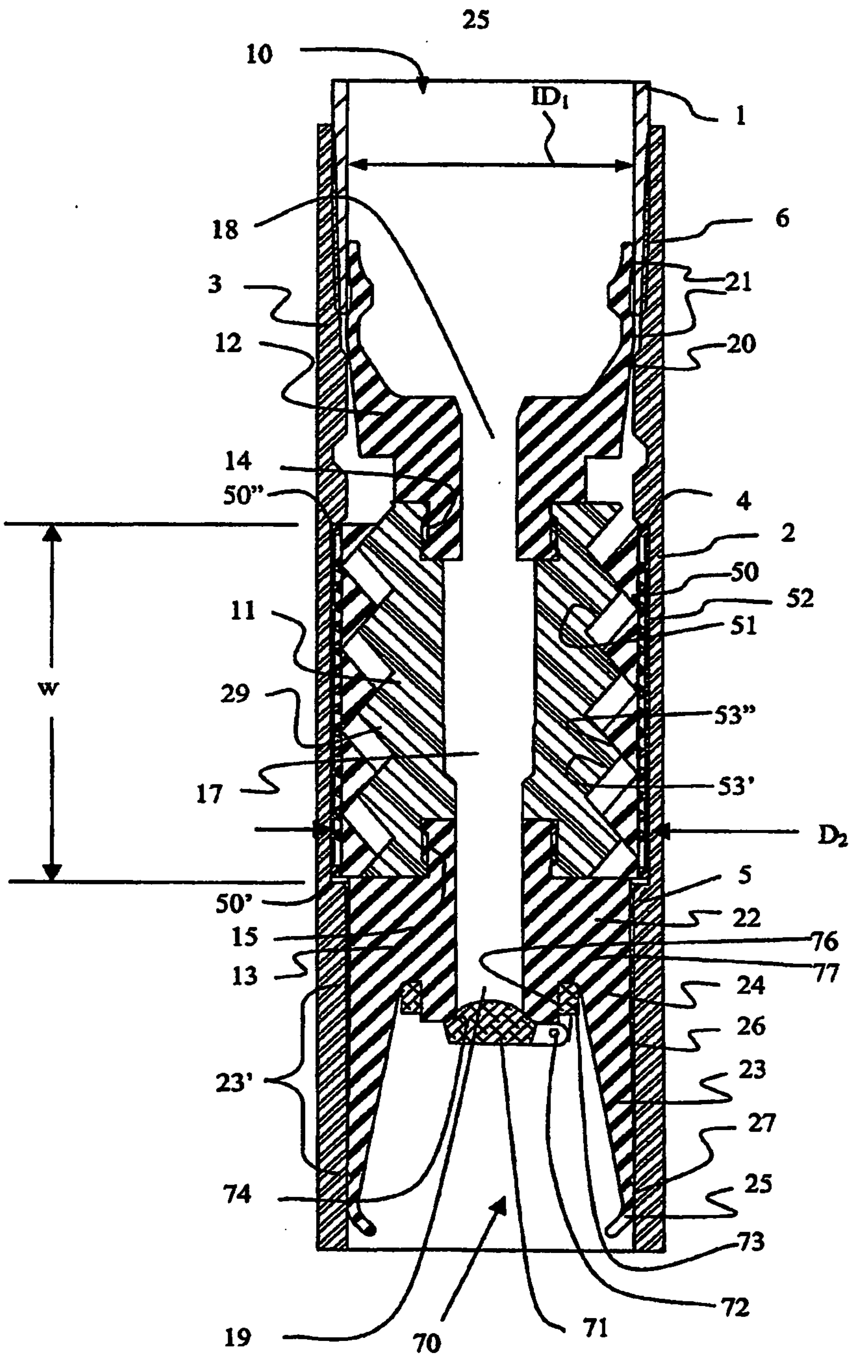
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Figure 3

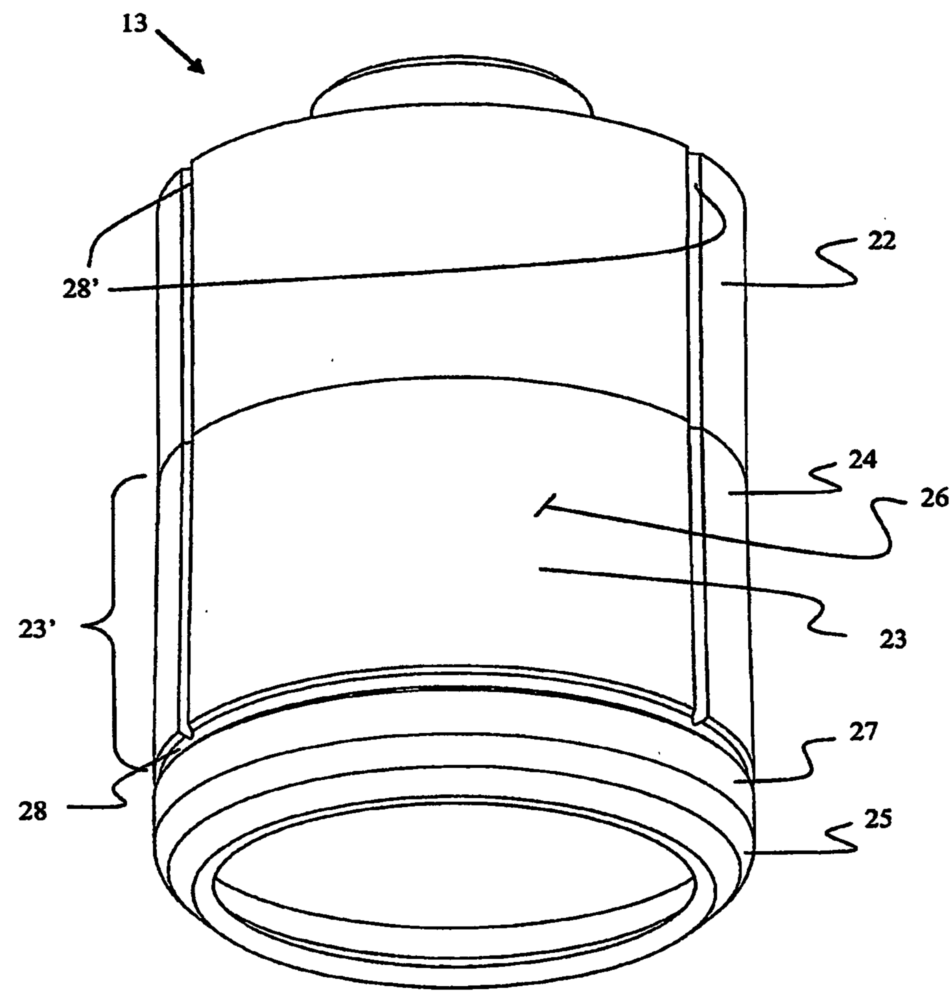

Figure 4

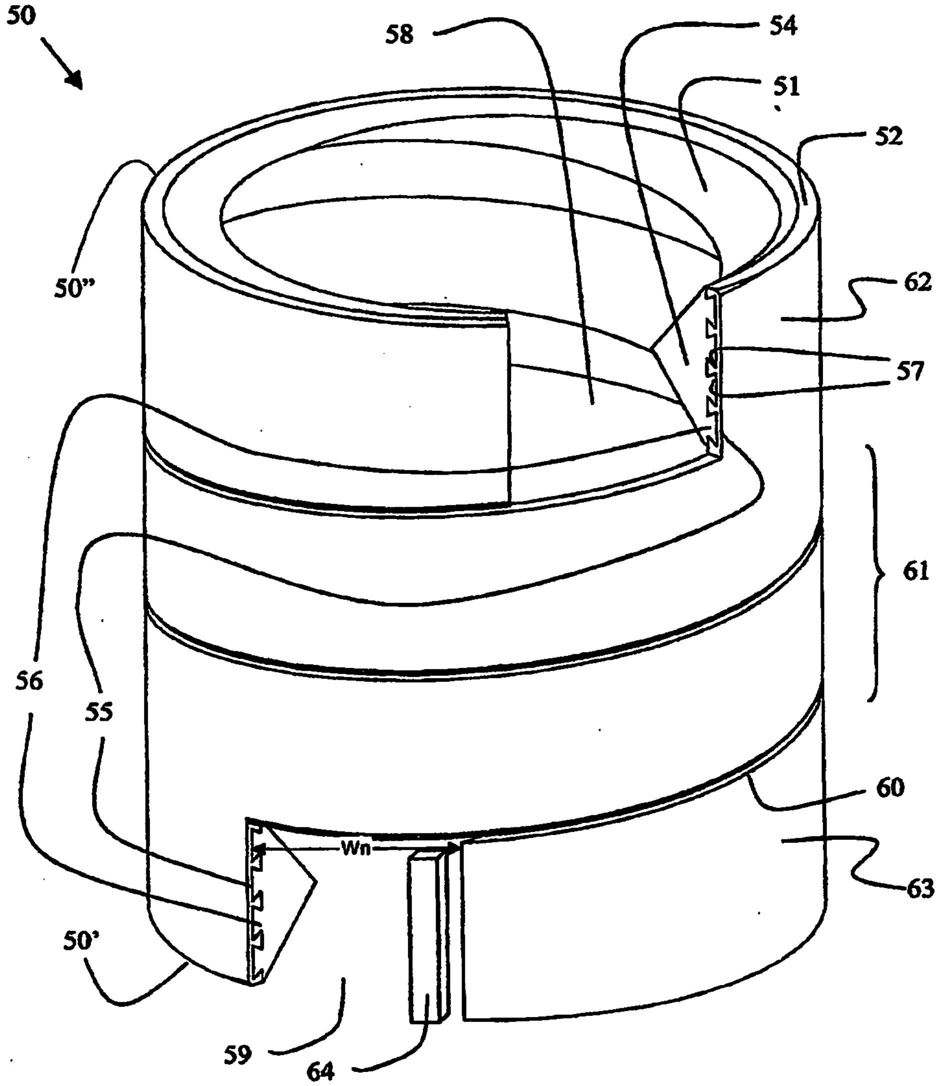

Figure 5

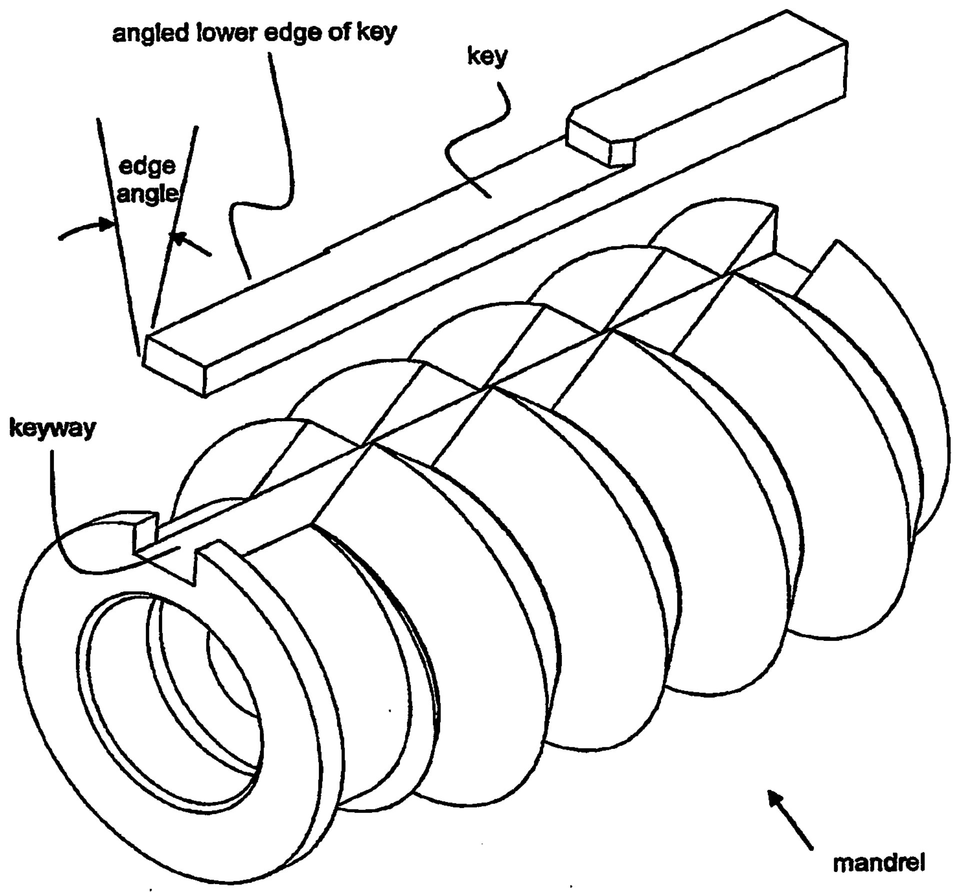

Figure 6

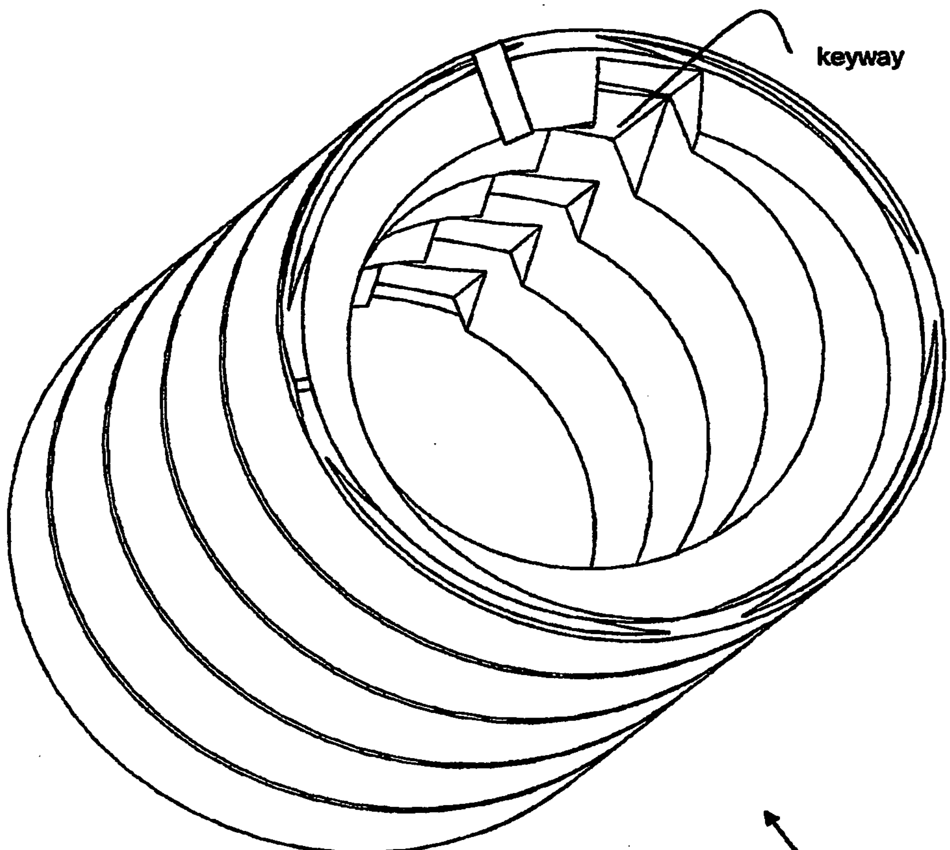

Figure 7